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The Development of the Command and Control Centre for Trial Kondari

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ABSTRACT

Trial Kondari was a TTCP sponsored activity to evaluate complementary harbour protection system components that could provide interdiction for underwater harbour threats, including; divers, underwater vehicles, and surface swimmers. A Command and Control (C2) centre was required to enable coordination of divers and boats, by providing a live common operating picture. The C2 centre also coordinated the logging of data for further analysis after the trial and allowed the viewing of remote displays. The design of the C2 Centre had to comply with several constraints including; short time frame, limited budget, Defence policies, and geographic distance. The solution, which will be described in this document, was cost effective, and addressed all of the requirements and constraints.

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Executive Summary

The Technical Cooperation Program Maritime Systems Group (TTCP MAR) established Action Group 9 (AG-9) to address the threat of underwater attacks, and hence deal with underwater force protection issues. AG-9 devised trial Kondari, whose objective was to evaluate complementary harbour protection system components to provide interdiction for underwater harbour threats, including; divers, unmanned underwater vehicles (UUV), and surface swimmers.

The purpose of creating the Command and Control (C2) centre for trial Kondari was to enable coordination of all the assets of interest in the trial through the use of a live common operating picture (COP). All divers and surface swimmers were accompanied by safety boats during the trial. Moreover many of the harbour protection systems incorporated a response boat that carried a sensor (typically a sonar) to investigate possible threats. The C2 system needed to be able to view the position of boats and divers, and possibly coordinate their movements. A live view of the operational picture was maintained by displaying the tracks from various components including; all the major sonar systems, divers, diver safety boats, and response boats. Boats were carrying Global Positioning System (GPS) devices and the divers were carrying an acoustic positioning device to enable tracking. In addition to viewing tracks, the console displays of the various sonar systems were shared so that they could be viewed and recorded in the C2 centre.

The C2 system also logged data for further analysis after the trial. The operational picture for each scenario, the logs of GPS devices, video captures of the shared console displays, and other miscellaneous data were all captured and stored onto a Network-Attached Storage (NAS) device for backup. The analysis of this data will enable the AG-9 to determine which harbour protection system components were most suitable.

Contents

Abbreviations

AIS	Automatic Identification System
C2	Command and Control
C2PC	Command and Control Personal Computer
COP	Common Operating Picture
ENM	EPLRS Network Manager
EPLRS	Enhanced Position Location Report System
ETA	Estimated Time of Arrival
FCP	Fleet Concentration Period
GAPS	Global Acoustic Positioning System
GCCS	Global Command and Control System
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile communications
ICS	Interoperable C4I Services
IP	Internet Protocol
ISM	Information and Communications Technology Security Manual
KVM	Keyboard Video Mouse
LSCL	Littoral Sea Command Laboratory
MOD	Maritime Operations Division
NAS	Network-Attached Storage
OTH-G	Over-the-Horizon Targeting Gold
PC	Personal Computer
RAID	Redundant Array of Independent Disks
RHIB	Rigid-Hulled Inflatable Boat
SCIS	Science Corporate Information Services
USB	Universal Serial Bus
UUV	Unmanned Underwater Vehicle
VNC	Virtual Network Computing
VPN	Virtual Private Network

1. Introduction

The Technical Cooperation Program Maritime Systems Group (TTCP MAR) established Action Group 9 (AG-9) to address the threat of underwater attacks, and hence deal with underwater force protection issues. AG-9 devised trial Kondari. The aim of this trial was to evaluate complementary harbour protection system components to provide interdiction for underwater harbour threats, including: divers, unmanned underwater vehicles (UUV), and surface swimmers.

This document discusses the Command and Control (C2) centre that was developed for the trial. The C2 centre enabled coordination of several divers and boats, through the use of a live common operating picture (COP). The C2 system also logged data for further analysis after the trial.

The timeframe for completion of the design and establishment of the C2 centre was five months before the trial began on February 2009. Kondari was held at Garden Island, NSW, and divers were at most 1 km away from the shores of Garden Island.

In section 2 of this document, the requirements and constraints that would mould the design of the C2 centre are outlined. Section 3 describes the plans, detailing the architecture of the C2, which satisfy the requirements and constraints. The results are described in section 4. A few recommendations are made after the conclusion in section 6.

2. Requirements and Constraints

There were a number of factors that the C2 centre had to address; a set of requirements, and a list of constraints.

2.1 Requirements

The design of the C2 was guided by a few requirements. The requirements list included the following:

- R.1. A live COP was needed to view, at minimum, the tracks of the safety boats and response boats.
- R.2. Data logging was needed for backup of data and post analysis.
- R.3. The console displays of various sonar systems needed to be viewed in the control centre. This requirement was highly desired, but not essential.

2.2 Constraints

In addition to the above requirements, there are a number of constraints that persuaded the solution design, and these include:

- C.1. Short time frame of five months to research, purchase, test, and troubleshoot all equipment.
- C.2. A limited budget to spend on I.T. related hardware and software.
- C.3. The data, which was unclassified, needed to be transmitted over a secure network.
- C.4. Defence policies [1] had to be considered when designing the network. In regards to the C2, these include; access to the Internet[1], privileged access by foreign nationals[2], cable runs between buildings[3], Internet Content[4], Defence Controlled Devices[5]. Radio Frequency and Infrared Devices [2] was of most concern despite the unclassified data being transmitted.
- C.5. The geographic distance had to be considered because data would be transmitted over distances of hundreds of metres to 1 km.

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[1] Section 2:50.64 of the eDSM
[2] Section 2:50.53 of the eDSM
[3] Section 2:50.68 of the eDSM
[4] Section 2:54 of the eDSM
[5] Section 2:52 of the eDSM

3. The Plan

There were a few possible solutions to the requirements and constraints listed in Section 2. A key requirement was the tracking of boats and divers on a live COP. In addition these track positions had to be logged for later analysis. In order to cover all bases, three plans were devised; ideal plan, basic plan, and the fallback plan. These requirements led to an architectural design which had common features across all plans. Each unit needed to transmit its location data to the C2 centre, with the live COP displayed at the C2 centre, and all the data stored at the C2 centre.

Our aim was to initially gather the feeds from various systems about diver and boat positions into the C2 centre. Then, if possible, we would integrate these feeds into a single COP. In this section further detail will be provided on these systems as well as a description of each of the plans.

3.1 Systems Overview

The GAPS system uses a diver attached transponder to send diver locations to its main sensor. The main sensor then sends its data to an operator terminal which can display the diver tracks as shown below and send a variety of messages to other systems. The Figure below is a screenshot of the GAPS operator display. The GAPS main sensor can be seen as the blue mark and the diver positions are points in red.

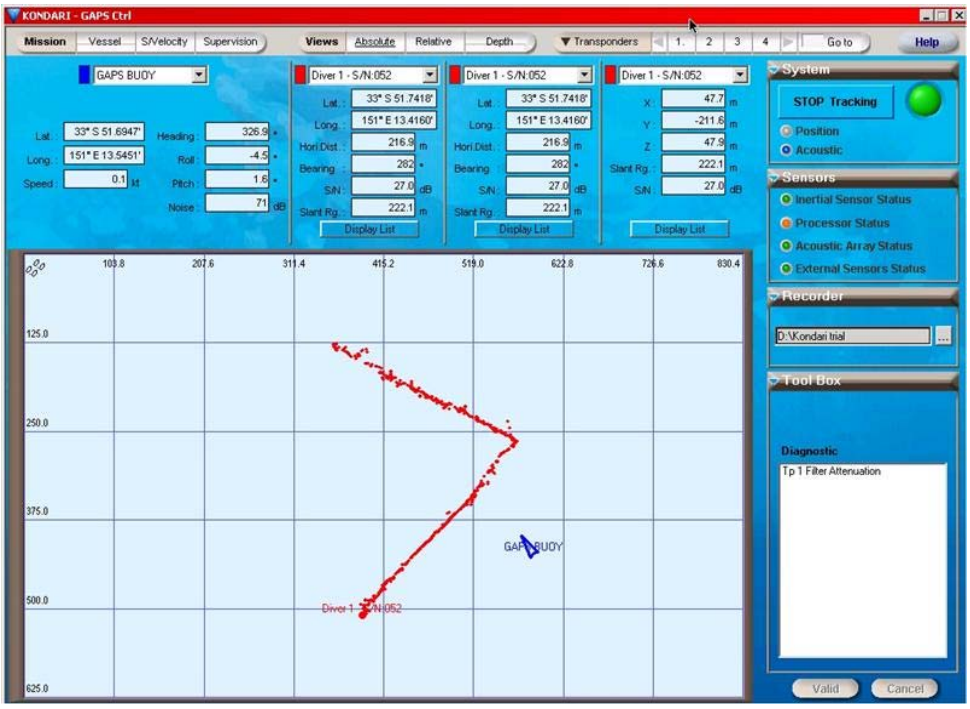

Figure 1: GAPS Operator Display

Sentinel and Cerberus were two of the sonar systems being demonstrated to try to pick up the diver tracks. Each of the sonar had a shore based control station which, much like GAPS, got data from its respective sonar array in the water and displayed this information to the operator in its own proprietary format. Figure 2 below shows an example of the Sentinel operator display as the sonar picks up a strong diver track moving north.

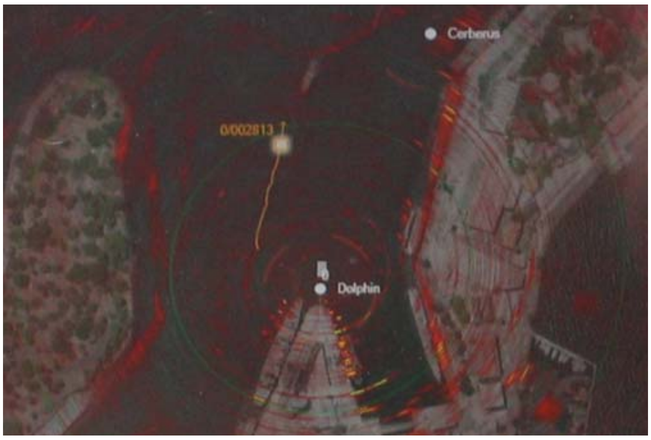

Figure 2: *Sentinel Operator Display*

Command and Control Personal Computer (C2PC) is a software known to be capable of displaying GPS tracks and can be used to display other tracks on a COP. Figure 8 is a screen output from C2PC. Google Earth is software, like C2PC, that can view tracks on a map. The plan was to use either C2PC or Google Earth to view the boat locations and possibly the tracks from GAPS, Sentinel, and Cerberus.

Interoperable C4I Services (ICS) needs to be used if C2PC is chosen as the COP display tool. ICS, a commercial variation to Global Command and Control System (GCCS), is a track management system. ICS is needed to manage the tracks received from the C2PC systems.

Figure 3 below shows Garden Island with the Boat Docking points and Cerberus Station. The red box indicates the zoomed version shown in Figure 4 below, where the Control centre and Sentinel Shore station are located. The two boat docking points were used for Diver and Response boats during the trial. The Diver boats dropped and picked up the divers during each run. They also shadowed the divers for safety and gave a visual clue, for surface observers, of the general proximity of the diver. The Response boats also had diver detection systems which needed to be viewed, or if possible integrated, in the Control Centre.

Figure 3: Locations of docking points and Cerberus Shore Station at Garden Island (© Google Maps)

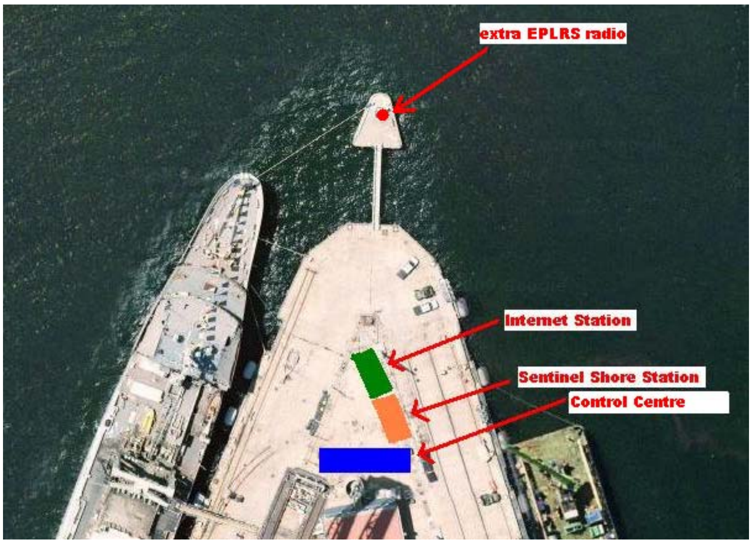

Figure 4: Garden Island Stations Setup (© Google Maps)

3.2 Fallback Plan

The fallback plan is the least "high-tech". It uses voice communications to transmit position data to the C2 centre. At the C2 centre, these positions are manually entered into a COP display tool such as C2PC or Google Earth.

Requirement R.1
Tracking safety boats and response boats for the COP would be provided through manual plotting on an electronic map. Each of the boat's start and destination locations are known through the serials, or can be gathered over marine radios. Plotting the boats requires knowledge of Estimated Time of Arrival (ETA) to the destination, as well as periodically stating the GPS location over marine radios. This solution is people intensive requiring a person for each radio, as well as several for the map plotting. Figure 5, below shows the network design for the fallback plan.

Requirement R.2
C2PC is known to be capable of displaying GPS tracks and can be used to display other tracks on a COP. C2PC or Google Earth would be the tool to display the electronic map. Logging of the plotted locations during serials would be obtained through the tool's logs or through the use of a desktop screen capture tool.

Data would be stored on a Network-Attached Storage (NAS) device that will backup the data through a Redundant Array of Independent Disks (RAID) system.

Requirement R.3
The fallback plan is the simplest solution that complies with most of the requirements and constraints mentioned earlier. The only one that it does not adhere to is viewing of sonar system console displays in the control centre.

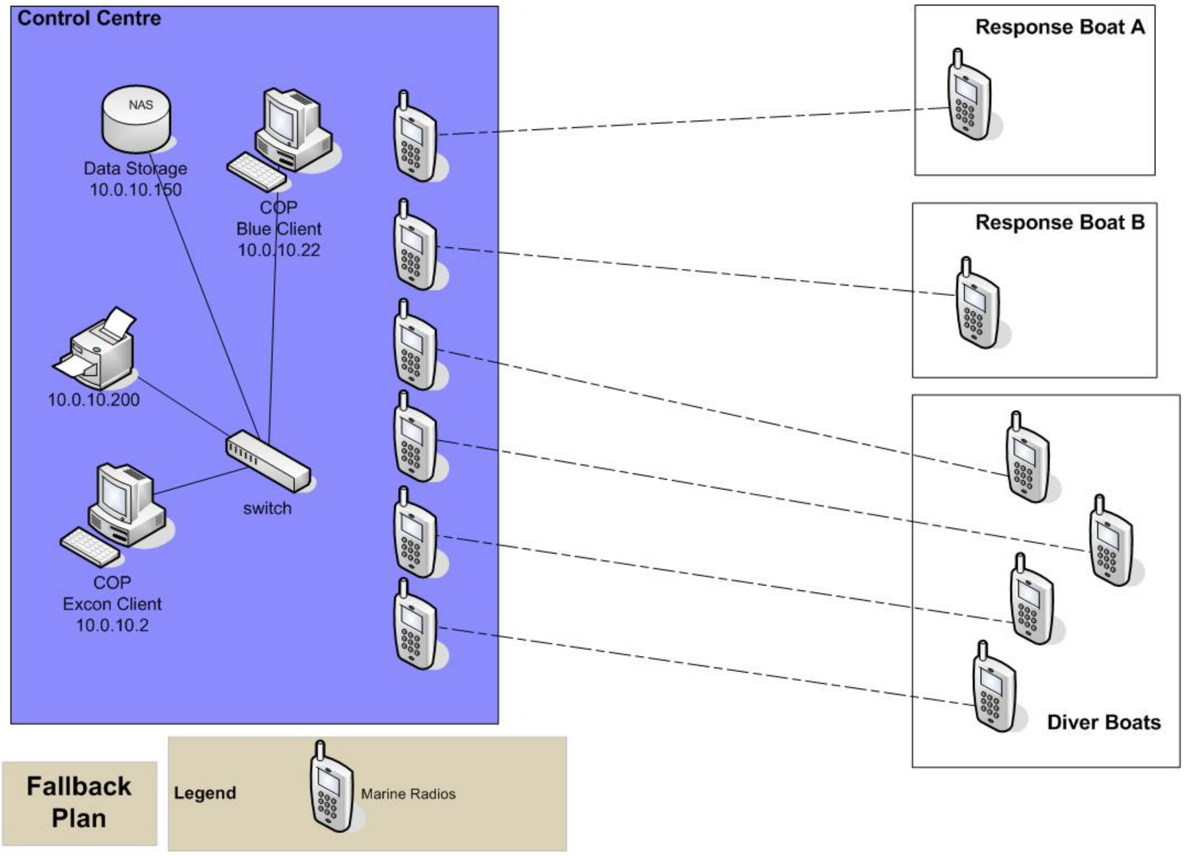

Figure 5: Network Design for the Fallback Plan

3.3 Basic Plan

For this plan, GPS data from the boats will be transmitted wirelessly to the C2 centre and will feed into C2PC or Google Earth. The VNC remote desktop tool will be used to remotely display the consoles from the various sonar systems.

Requirement R.1
Tracking the boats will also, by default, track the divers since the diver safety boats are physically located within 10 metres away from the divers. A device will need to be placed on the boat that will transmit its GPS location via wireless transmission. There are many wireless transmission mediums that can be chosen, each of which will be discussed in the following sub-section titled 'Basic Plan Options'.

Requirement R.2
The screen shares provided by Tight VNC can be recorded for backup purposes using another tool called Camtasia studio. Camtasia studio records the display on the screen and outputs it into various video formats such as mpeg, avi, flash and others.

The software used to display the tracks of the boats, will be the same software used to log the tracks. The software will be either Google earth, C2PC, or the software that accompanies the GPS hardware.

All the logs and screen recordings will be stored on a NAS device.

Requirement R.3
The C2 centre can view the console displays of the sonar systems, which are physically located 5 metres to hundreds of metres away, using a software tool called Tight VNC. Tight VNC can send screen captures, at a rate of once every 300 ms, of the host computer to the remote viewing computer over a slow network.

3.3.1 Basic Plan Options

The C2 centre cannot be physically connected to all the sonar systems, and therefore will require a means to transfer data wirelessly. There are many options for wireless transmission, which will be discussed in this section.

A list of wireless options includes:

- Marine radio with GPS
- AIS
- BAE Spider
- Wi-Fi
- GPRS / GSM with GPS
- Telstra Next IP
- EPLRS

Some *marine radios* come with GPS built-in, and each boat can have a marine radio to transmit its GPS location periodically. This solution is slightly better than that mentioned in the fallback plan. However, it was still not ideal for it to be part of the basic plan because a software tool needed to be developed to integrate the GPS locations into a COP. Also, it does not provide a transmission medium for displaying the console displays of sonar systems.

Automatic Identification System (AIS) typically provides ship location information using GPS. Other additional information is also added such as ship name, type, dimensions, and ETA. The cost associated with setting up AIS transponders on each boat was estimated to be above $1000 which was close to the budget limit. It would also be preferable if the device was also capable of transmitting video feeds.

BAE's Command and Control System called *Spider* was initially considered because it integrates various sonar system tracks into a COP, and it also was guaranteed to work with Cerberus (one of the underwater intruder detection sonars). However, due to its lack of integration with the other sonar systems, as well as a lack of integration with GPS data, we decided not to pursue the Spider system. Enhancing the Spider for our needs was considered, but this would require more development time, with possible high costs associated with it.

Wi-Fi allows for a standalone and encrypted setup. However, a network using Wi-Fi needs access points located in high vantage points for line-of-sight connectivity to the end-point. It would be difficult to find suitable locations to place the Wi-Fi access points around Garden Island due to the changing environment.

There are many devices that utilise *General Packet Radio Service (GPRS)/Global System for Mobile communications (GSM)* technologies for wireless communication. A number of them were reviewed and some were quite suitable for the project. One of the notable ones is called the C1 Mobile GV511, which utilises the GPRS/GSM network to transmit the GPS location of the device.

Telstra's Next IP network architecture utilises the GSM 3G mobile communication technology. The Next IP network was desirable to pursue because it provides a closed network environment over the public mobile network. In addition to that, secure lines can be enforced by adding a Virtual Private Network (VPN) layer on top of the Next IP closed network.

Enhanced Position Location Reporting System (EPLRS) is a wireless architecture being considered by the Australian Army for voice and data communications. EPLRS allows for a standalone and encrypted setup just like Wi-Fi. It also works on line-of-sight connectivity between radios that need to be set up around Garden Island.

3.3.2 Best Choice for the Basic Plan

The list of wireless options has so far been culled down to utilise either:

- Wi-Fi,
- GPRS/GSM,
- Telstra Next IP, or
- EPLRS.

To keep costs down, the hardware of choice are the tablet PCs available from the Littoral Sea Command Laboratory (LSCL). By acquiring gear from other groups within Maritime Operations Division (MOD) any purchasing delays are eliminated.

C2PC was purchased by Defence under a Defence wide licence and the LSCL have C2PC installed on each of their tablet PCs.

The best choice is to utilise the hardware and software already at hand. Also the combination of tablet PCs with C2PC has been tested for use to transmit GPS locations from large naval ships and Rigid-Hulled Inflatable Boats (RHIB) from a previous trial [3].

Utilising the readily available hardware eliminates the use of GPRS / GSM devices such as the C1 Mobile GV511. Both the Wi-Fi and EPLRS transmission mediums require line-of-sight with either access points or radios that require set up around Garden Island. This kind of network architecture increases likely failure points. So the only option that was left was to use the Telstra Next IP network. The Next IP network also relies on line-of-sight connectivity, but with cellular towers which have high vantage points, much greater than any manual setup that could be achieved through placement of access points or radios on Garden Island.

There were two companies that utilised Telstra's Next IP network each with their own pros and cons. Call Direct was able to establish the desired network in a few minutes, and their modems catered for VPN customisation. However, the network they provided comes coupled with their modems which cost twice as much as Telstra's Next G USB modem. Telstra's Next IP network configured through Telstra and using Telstra USB modems was far more costly on initial review because of setup costs. However, a Defence colleague had already purchased a large quantity of Telstra sim cards that were configured for Telstra Next IP with VPN security. Therefore, the chosen implementation of the Telstra Next IP network was using Telstra's configured network using their USB modems.

A diagram of the Telstra Next IP network is portrayed in figure 6. The diagram shows the C2 centre inside a blue bubble whose modems have privately assigned IP addresses which are authenticated by Telstra's radius server. No other sim cards can communicate on this private network unless authorised by the radius server. The Next IP network is a network bubble within the larger Next G network.

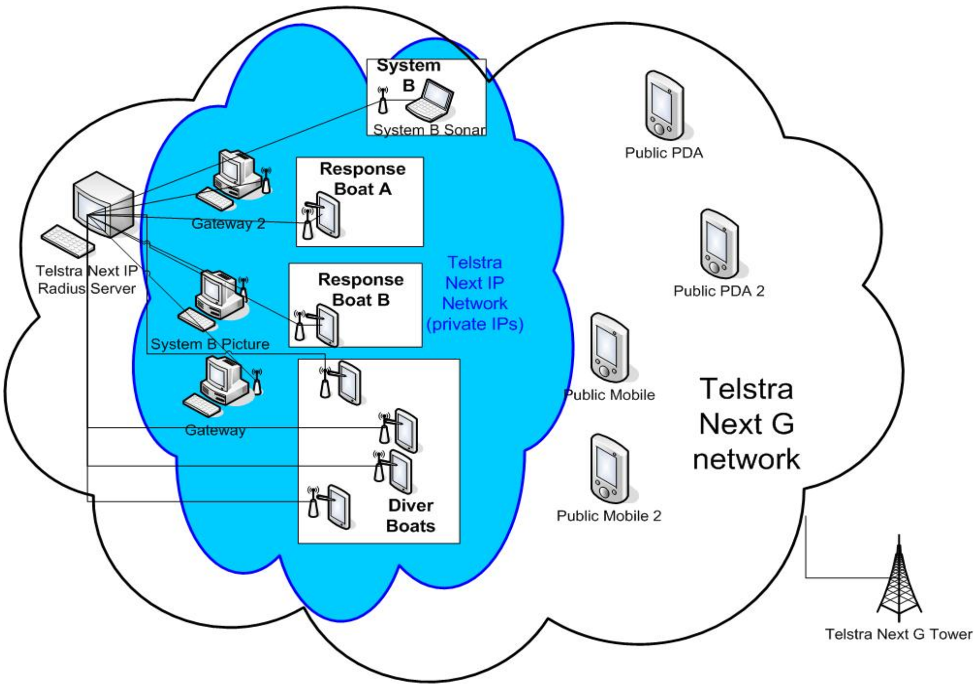

Figure 6: Telstra Next IP Network

3.3.3 Post-Test Choices and Solution

The outcome was unsuccessful for several tests when using C2PC to transmit GPS locations via Next IP. The burst-like connectivity, where dropouts are common, was the cause of failure. The dropouts remained a problem even after various changes to C2PC's configurations. The Next IP network; however, was a good transmission medium for sharing the console displays of various computers/sonar systems using Tight VNC as the screen sharing application. Tight VNC catered for dropouts and low bandwidth connectivity.

Time was drawing nearer to the trial and there was not enough time to pursue other GPRS/GSM devices. Keeping with the combination of tablet PCs and C2PC application, the EPLRS radios were trialled as an alternative to Telstra's modems. The EPLRS radios were the next ideal choice over Wi-Fi access points because they have previously been used with the same hardware and software in a similar type of environment.

Prior to the trial, the EPLRS radios were tested in Canberra, and did not work as well as expected. During the tests, radio connectivity was an issue, after a few minutes it would drop out. This was most likely due to data bottlenecks from limited bandwidth while transferring screen shares, using Tight VNC, over the network. TightVNC takes up approximately 300 kbytes (2400 kbits) per second bandwidth, while the radios maximum potential is 1 Mbit per second (1024 kbits per second). It was falsely assumed that its maximum potential was 1 Mbyte per second. In the end the EPLRS radios were set to 300 kbits per second for reliability, and no screen sharing was to be sent over this network.

A hybrid solution using both the EPLRS and Next G modems ended up being the final solution, where the EPLRS radios transmitted the boat locations, and the Next G modems provided the screen shares.

Another issue of concern was the use of GCCS in an unclassified environment. GCCS' use has been limited to secret environments, and therefore a commercial variation to GCCS called ICS was used. MOD had previously bought a licence for ICS and it was available in LSCL.

The basic plan's final solution (shown in figure 7) comprised of the following items of hardware:

- Tablet PCs with built-in GPS
- Next G modems, which are depicted in figure 7 as aqua antennas
- EPLRS (Enhanced Position Location Reporting System) vehicle radios, which are depicted as green antennas
- EPLRS microlight (man-portable) radios, which are depicted as white antennas
- C2PC Blue Client – displays all the blue tracks; response boat tracks and sonar detections. This machine will also act as a secondary C2PC gateway.
- C2PC Excon Client/COP – displays all tracks; all blue tracks, diver boats, and diver tracks. This machine also acted as the primary C2PC gateway.
- NAS – a data storage device configured with RAID 5.
- ICS – manages all the tracks to be displayed on C2PC.
- Printer
- Classification – displays a screen shares of any of the classification sonars mounted on the response boats.

- Cerberus – displays a screen share of the Cerberus console display.
- Sentinel – displays a screen share of the Sentinel console display.
- Global Acoustic Positioning System (GAPS) – a port on the switch will be left available for the GAPS system, which tracks the individual divers.
- Windows server and time server machine – acts as a DHCP server assigning IP addresses, and it also acts as the time server for all machines on the network.
- EPLRS Network Manager (ENM) radio – authenticates and manages all the EPLRS radios.

The basic plan’s final solution comprised of the following software applications:

- Command and Control Personal Computer (C2PC)
- Interoperable C4I Services (ICS) – An unclassified variation to Global Command and Control System (GCCS)
- Tight VNC (Virtual Network Computing)

Outside of the C2 centre there were numerous sonar systems and boats, which are listed as follows:

- Diver boats –will be tracked using the Tablet PC’s GPS device, which transmits the location over EPLRS microlights.
- Cerberus – is a sonar system that will have an EPLRS land vehicle radio to transmit the sonar detections to ICS. In addition to that it will also have a Telstra modem to transmit its screen share to the C2 centre.
- Sentinel – is a sonar system that will be located adjacent to the C2 centre and will share its data via an Ethernet cable.
- Response boats – will be tracked using the Tablet PC’s GPS device like the diver boats. The sonar systems on these boats will also have Telstra modems attached to them so that their console displays can be shared with the Classification machine in the C2 centre.

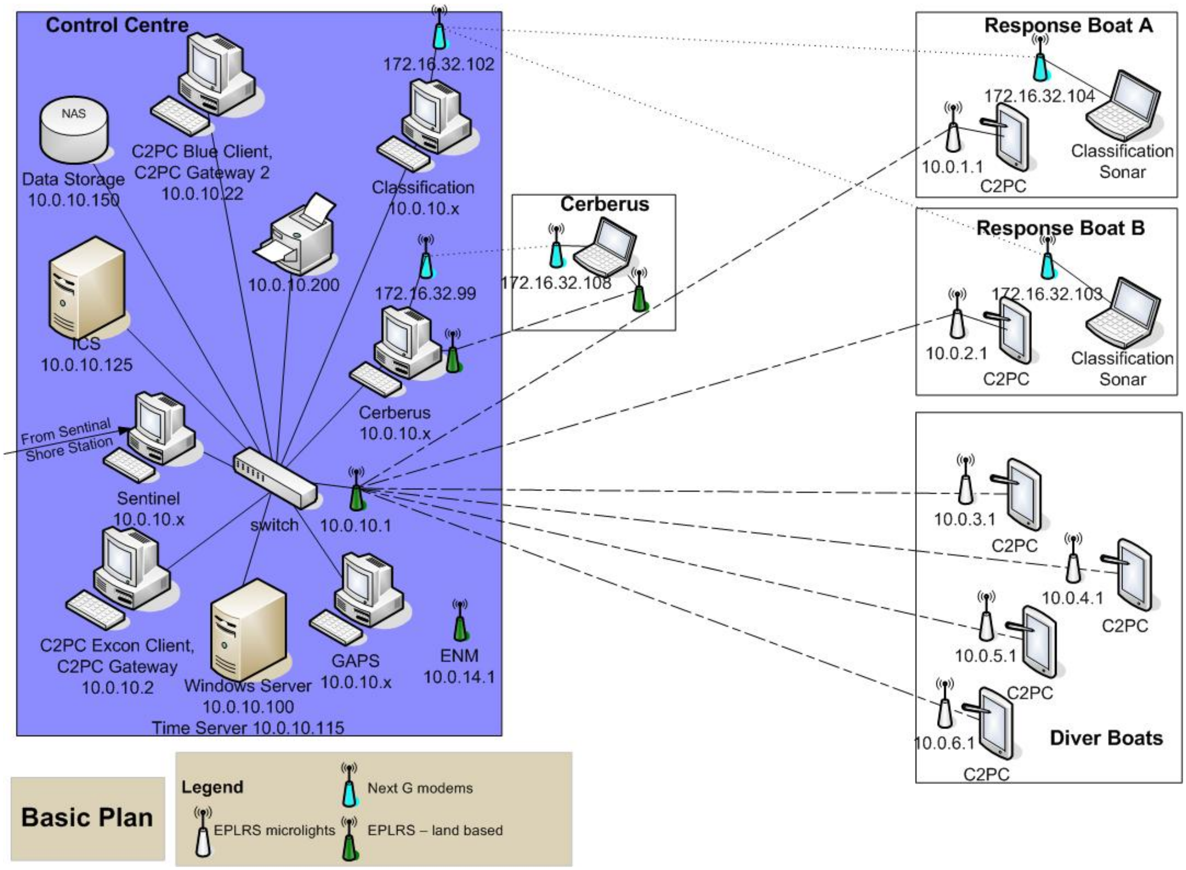

Figure 7: Network Design for the Basic Plan

3.4 Ideal Plan

The basic plan and the ideal plan were very similar in their design. The only difference is that the ideal plan would integrate all the sonar tracks into the C2PC COP. The hardware setup would be identical and therefore achieving requirements R.2 and R.3 would be identical to the basic plan. This section will discuss requirement R.1; how track integration was achieved for the live COP, which is a software problem. Thus, the diagram in figure 7 which portrays the network design for the basic plan is the same design for the ideal plan.

Apart from the C2PC tracks, an integration of three external systems needed to be implemented into the COP:

- GAPS, a diver tracking system which used diver fitted transponders to relay diver information to a base station
- Sentinel, an underwater intruder detection sonar designed to protect high value marine assets by detecting and classifying threats.
- Cerberus, similar to sentinel, is an underwater intruder detection sonar.

Diver boats:
As in the basic plan, boat teams, both diver and response, carried with them tablet PCs fitted with C2PC, GPS and a radio. These radios connected directly to the C2PC network and updated the COP with their respective boat positions throughout the trial.

GAPS:
The GAPS system was located in the control centre near the ICS machine and this allowed easy data transfer. Figure 9 in Appendix A shows the location of the GAPS and ICS machine. GAPS had a few ways to output data live; the one that was used was its proprietary serial output format. A laptop will sit in between GAPS and ICS, and a DSTO-written translator software will read in the serial output from GAPS, select the diver tracks and convert this output to an Over-the-Horizon Targeting Gold (OTH-G) message format. This OTH-G message will then be passed to the ICS machine via a serial cable, and the diver tracks will be viewed on the C2PC COP.

Sentinel:
The Sentinel Sonar system sent its track messages via a network port in a proprietary binary format. The output will be connected to a laptop which will use a DSTO built program to read in these track messages and convert them to OTH-G. The converted message sets will then be passed to ICS via a network cable. Network cables will be used as the Sentinel shore station was right next door to the Control centre, as can be seen in Figure 4.

Cerberus:
The Cerberus Sonar system processed and passed its messages in the same format as Sentinel, except the tool to convert the messages will be provided by the Cerberus team. The OTH-G messages will be piped to ICS over the network using a spare radio as the Cerberus shore station will be too far away for a network cable as can be seen in Figure 3.

3.5 The Implemented Plan

The approach was to implement the ideal plan, with the basic plan as the alternate if the integration of sonar tracks proved problematic. Prior to the trial, an attempt was made to find ways to pass the track data that the various sonar systems generated to the ICS. The methods used were not able to be functionally tested until the trial started and hence there was a high risk attached to this task. Collaboration with the teams initially over email, finally in person, aided the completion of this task. Therefore, in the end the ideal plan, whose hardware setup was identical to the basic plan, was the applied C2 solution.

The resources used to implement the solution included two DSTO staff, authors of this document, working full-time on the project designing and implementing the hardware and software tools. These two staff members collaborated with the technical specialists of the various tracking gear used in the trial.

The cost of the hardware was kept at a minimum since various bits of gear were borrowed from other groups within Defence. The software cost was nil because no software needed to be purchased, they were mostly pre-purchased items, and new software was developed in-house. Overall, the cost of all the gear was attributed to the hardware at a total of approximately $10 000.

4. Results

4.1 Overall Result

A live COP was provided that integrated all of the required sonar systems, divers, and boat tracks into a single COP. The logs of these tracks were saved after each scenario, and in addition to that video recordings of the COP screen were also saved. The console displays of the sonar systems were viewed in the C2 centre and their screens were also recorded for backup. All saved data was stored on a NAS.

The figure below shows a screenshot of the C2PC COP from a live trial. Tracks were given unique symbols and colours to differentiate them from each other. Observers could easily see on one screen where the diver and response boats (blue) were, where divers were (red), and also where both Sentinel and Cerberus (green) were picking up contacts.

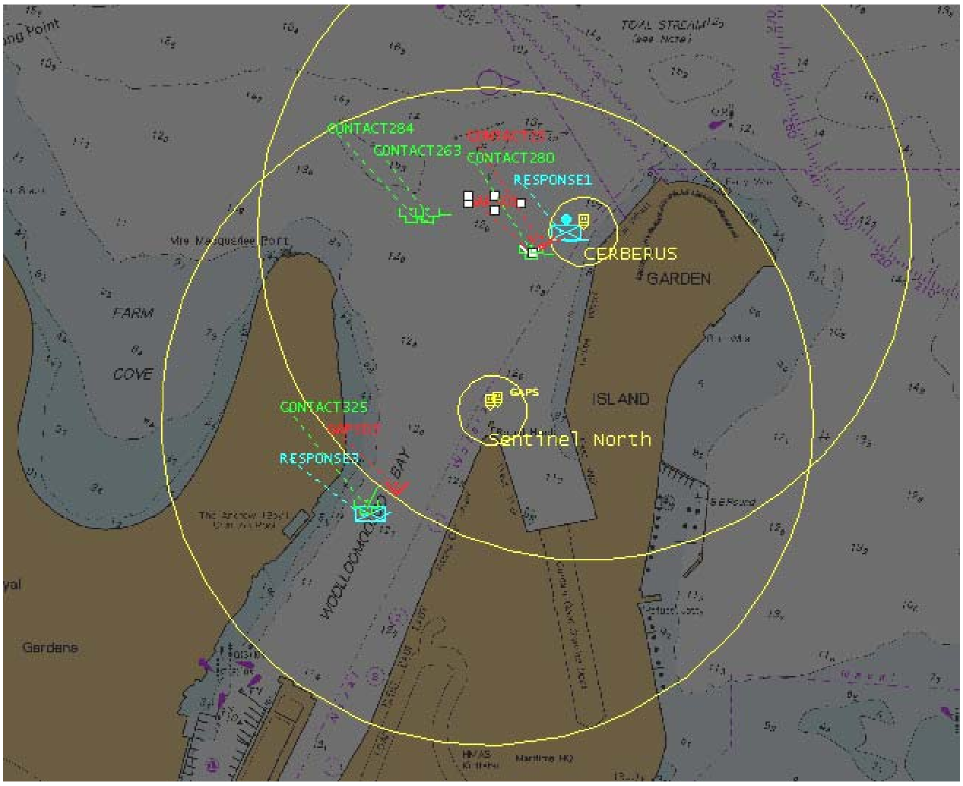

Figure 8: Common Operating Picture displaying boats, diver contacts, and sonar locations

4.2 What Worked

- The EPLRS radios, on most occasions, were able to send GPS tracks every 5 seconds at a furthest line-of-sight distance of 1.5 km
- The Next G modems, on most occasions, were able to screen share via Tight VNC. The distance to the nearest cell tower was unknown. Tight VNC works by taking screenshots of the desktop, compressing it, and then sending that to the remote computer.

4.3 What Did Not Work

- In regards to both the EPLRS and Next G, on some occasions, it was hard to pin-point exactly what caused the transmissions to stop working. There are many factors that could have contributed to it not working effectively which is discussed next in section 4.3.
- Bandwidth limitations of the EPLRS radios restricted its use as the transmission medium for screen sharing.
- Two IP addresses were supplied to a single computer, when the Next G modem and the local area network (LAN) are connected simultaneously. In most cases traffic did not flow to the IP of the Next G modem. The resolution was to set a static path to the Next G modem through the routing table.

4.4 Factors Affecting the Wireless Transmissions

Despite the pre-trial test day working flawlessly, during the trial some of the serials did not work so well due to degradation in the transmission quality between devices.

- Factors affecting the EPLRS network include interference and attenuation from:
  - Large objects – large metal objects such as ships and cranes deflect the RF signals, and also slightly absorb the signals. Buildings around the naval base block the signals.
  - Ships could also be turning on their RF devices on occasions, using similar frequency bands.
  - Sea – deflects the RF signal. Small boats were used to carry the microlights and were therefore low on the sea-level.
  - Line-of-sight – radios seemed to only work at about 1.5 km at most. However, at this distance the pings were dropping out a lot and only 0.05 pings were successful. This was much worse than during the test day, possibly because on the test day there were two boats out where the signal can hop between before reaching the destination point on land. A hop is the journey a signal makes across a transmission link between two devices.
  - Rain – absorbs much of the antennas transmitting power

- Factors affecting the Next G network include interference and attenuation from:
  - Sea – deflects the signal.
  - Multiple cell towers – the modem would probably have to switch between various cell towers as the boat moves around the harbour.
  - Rain – absorbs much of the antennas transmitting power.
  - Line-of-sight – blocked by ships and buildings, and distance between transmission devices may have been too far.

It was hard to pin-point exactly what affected the network especially because every serial was different. If it was not one or a combination of the factors mentioned above, then it was the serial's scenario itself which caused problems. Every serial was designed to be different and each had:

- Varying numbers of boats - the more boats there were the more effective the EPLRS radios would work because the data can hop between radios.
- Varying boat starting points – boats were docking at various points around Garden Island, and each had different obstacles blocking the line-of-sight. This was a major problem particularly when the boats docked on the eastern side of Garden Island (see Figure 3), which was the furthest docking point from the control centre. Eventually procedures were changed so that the tablet PCs were passed onto the boats from a point near the control centre, which is also depicted in Figure 3. This helped ensure that all the settings were working before the boats ventured off through their courses.
- Varying boat courses – during serials boats travelled through different paths, some being very far from the control centre, some close by, some with no line-of-sight.
- Different assessors – each serial had a different person handling the tablet PCs, which made it particularly difficult if they lacked the experience and knowledge of troubleshooting the tablet PCs when something went wrong.

Other factors:
Fleet Concentration Period (FCP) movement – Kondari was run during the time of Navy's FCP. During this period there was lots of ship movement. This was not particularly good for the wireless transmissions and also made it very difficult to pin-point the actual issues affecting the network.

4.5 Improving Network Connectivity

A number of changes were made to improve connectivity between the radios. Changes included:

- The docking point of the tablet PCs changed from the eastern side of Garden Island, where connectivity was very bad, to a point near the control centre (see Figure 3). The eastern side was initially the docking point because it was also the docking point for the boats. On the eastern side, assessors could carry the tablet PCs onboard with them; however, at the control centre the tablet PCs had to be hoisted down to the boats.
- The EPLRS antenna in the control centre was raised to a higher point. At least 3 metres higher.
- An extra EPLRS radio was placed at the tip of the island, shown in Figure 4, near the control centre.

Apart from these changes, over time other factors also helped the network connectivity and these include:

- Approximately two days into the trial, the serials had the boats travelling only a few hundred metres away from the control centre.
- Also approximately two days into the trial, the serials had more boats involved.
- Over time assessors handling the tablet PCs eventually understood enough to troubleshoot most of the problems themselves.

Since all these changes occurred generally at the same time. It was difficult to determine exactly what helped improve the network connectivity.

4.6 Lessons Learnt

- A project of this size and importance should require a year to design and deploy the I.T. side of things, especially if the environment where the equipment will be run is a virtually untested environment. Equipment such as modems have not been tested for transmission quality out at sea, at low heights above sea level, where signal quality degrades because of signal deflection by the sea. Modems are generally built and tested for office use. The main lesson learnt from all of this is that more time and people were needed to research, procure, and test networks.

- Purchasing times should not be underestimated as unexpected events can occur. For instance, it took over a month to deliver the sim cards, because they got lost in transit over the mail. More time for the project is needed to cater for procurement.

- All boat assessors who are to use the tablet PCs should have a good I.T. background, to enable troubleshooting of any problems.

- The short time frame for completion of the I.T. side of the project did not actually leave much time to train assessors on the tools they were going to use. Training assessors early so that they feel confident about the tools, i.e. tablet PCs, they needed to use before the trial is essential. A few days was allowed for self training, where assessors were handed out 'how to' documents to read through and have hands-on self training. Before the trial began, a quick instructor led training session was held. More time for training would be needed to discover issues that were not clear enough in the instructions, and to ensure confidence in handling the tools is instilled in the assessors.

- Communications between the people in the control centre and the people on the boats could have been better established. The Exercise Controller (Excon) could communicate with the people on the boats, but there needed to be another channel where technical aspects, that were not part of the general serial operation, could be communicated. CB radios were planned for this sort of communication, but they were never tested and never worked reliably during the trial. Instead, communications were achieved through expensive personal mobile phone communications. A better alternative would be to give each of the main Kondari team members Defence mobile phones.

- When using an off-the-shelf C2 system there is always the possibility that it will not be able to communicate with one or more devices automatically. In these instances, a translator tool will need to be created for the C2 to communicate with the device, providing that the interface protocols are provided by both the C2 and the device. For the trial, translator tools were created to communicate with Sentinel, Cerberus, and GAPS. Ample time must be set aside to create these tools.

- The use of satellite transmissions, though costly and out of the budget for Kondari, would have bypassed most of the environmental factors affecting the network.

- The use of Automatic Identification System (AIS) was initially not considered because of the cost of setup. Also, it was disregarded because we would still need some other technology to transfer the screen shares. However, this could potentially be a good alternative solution for transmitting boat locations, if time and money permits. Originally the cost of setup for AIS was significantly more than the cost of setup for EPLRS; however, there were unforeseen costs associated with the EPLRS. Cables for the EPLRS needed to be purchased because previous cables were broken through wear and tear. These cables were expensive and made the cost of setup for the EPLRS similar to that of the AIS.

5. Conclusion

Rigorous plans ensured that the C2 centre was successfully implemented and was able to satisfy all of the requirements and comply with all of the constraints, discussed in section 2, in a cost effective manner.

The C2 centre successfully captured and stored data for the Technical Cooperation Program Maritime Systems Group to analyse.

There are many sources of interference, discussed in section 4.3, when wireless communications are used for establishing a C2 centre in a naval base. The naval base proved to be a challenging environment for maintaining network connectivity.

6. Recommendations

Further studies into the use of wireless devices, in a naval base environment, need to be carried out to investigate the factors that affect wireless transmissions and how to mitigate them.

When similar trials are conducted, the lessons learnt from this trial, listed below and mentioned in detail in section 4.5, will be of useful reference.

- A project of similar size and importance will require a year to design and deploy the I.T. infrastructure.
- Time spent on purchasing equipment should not be underestimated and should factor in delays.
- All people who are to use I.T. equipment, which are critical to how the trial is conducted, needs to have an I.T. background because of their troubleshooting experience.
- All people using software tools, which are critical to how the trial is conducted, need to be given adequate training.
- The communication of technical issues between boats and the on-shore base needs to be separate from other discussions such as serial operation.
- Some devices do not automatically communicate with the C2 system and time must be set aside to create translator tools.
- Satellite transmissions could be used as an alternative means for data transport.
- Automatic Identification Systems could be used to transmit boat locations.

7. References

1. The electronic Defence Security Manual (eDSM) http://intranet.defence.gov.au/dsa/DSM/chm/index.htm#page=Part%202%20-%20ICT.htm May 2010

2. The Australian Government Information and Communications Technology Security Manual (ISM) http://intranet.defence.gov.au/dsa/DSM/chm/scr/forms/ISM.pdf May 2010

3. Gray, J. and Franco S. "Summary of the Trial held 17th – 23rd June 2007 during Exercise Talisman Sabre (U)" June 2008.

Appendix A: Network Design

A.1. Physical Network Layout

Figure 9 shows the physical setup for the C2 centre, and is drawn to scale. The office being used is a 30' container with five windows and one entry door. There are six 10 amp double outlets, and two 10 amp single outlets.

- Essentially all the computers, NAS, and the radio were connected to the switch.
- C2PC Blue, classification sonar, Cerberus, and Sentinel were connected to the Keyboard Video Mouse (KVM) switch. The console output was the plasma screen.
- Red cables are antenna cables.
- Next G modems will be attached to Cerberus and Classification Sonar computers.
- A long Ethernet cable was attached to Sentinel console via the Sentinel container nearby.

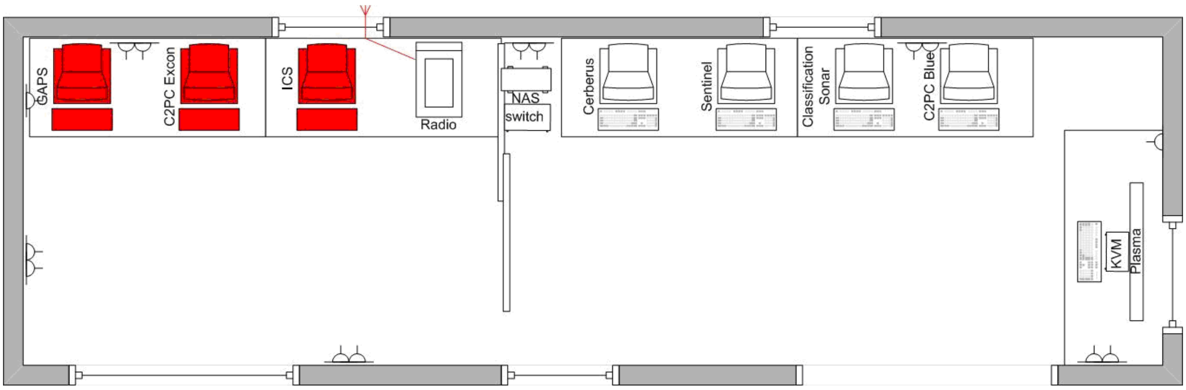

Figure 9: Thirty foot container setup

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19. ABSTRACT

Trial Kondari was a TTCP sponsored activity to evaluate complementary harbour protection system components that could provide interdiction for underwater harbour threats, including; divers, underwater vehicles, and surface swimmers. A Command and Control (C2) centre was required to enable coordination of divers and boats, by providing a live common operating picture. The C2 centre also coordinated the logging of data for further analysis after the trial and allowed the viewing of remote displays. The design of the C2 Centre had to comply with several constraints including; short time frame, limited budget, Defence policies, and geographic distance. The solution, which will be described in this document, was cost effective, and addressed all of the requirements and constraints.